same horses from 9 A.M. till 9.30 P.M., without halting more than a few minutes, none of them being apparently the worse for it, and a sucking foal following its mother during the whole journey. The horse which I rode accomplished the last hour of the journey at a canter in the dark.

In conclusion I would strongly urge upon any one who may think of visiting the country, that a knowledge of the Russian language is almost indispensable; and considering the large amount of valuable material which is practically buried in Russian scientific journals, I am surprised that so few English naturalists have hitherto thought it worth their while to do what many young Army Officers, for military purposes, now do every year.

Some Observations on the Caudal Diplospondyly of Sharks. By W. G. Ridewood, D.Sc., F.L.S., Lecturer on Biology at St. Mary's Hospital Medical School, London.

[Read 19th January, 1899.]

It is a well-known fact in Ichthyology that in Selachian fishes the vertebræ of the tail are twice as numerous as the caudal segments, delimited by the spinal nerves and the intermuscular septa.

The first clear reference to this remarkable phenomenon occurs, curiously enough, in Götte's memoir on the development of the Fire-bellied Toad (*Bombinator*), (**6.** p. 418, footnote). It has since been remarked upon by von Ihering (**9.** pp. 220–236), Hasse (**7.** p. 21), Balfour (**1.** p. 455), Schmidt (**15.** p. 756), Mayer (**13.** pp. 262–267), Gadow (**4.** pp. 194–196), and others.

To each myomere and neuromere there occur two centra, two pairs of crural plates, two pairs of intercrural plates, and four neural spines. The two centra are similar*, as also are the hæmal arches and the neural spines, but the crural plates are alternately imperforate and perforated by the ventral nerve-root, while a similar relation exists between the intercrural plates and

* Except in *Galeus*, in which they are alternately slightly longer and shorter.

the dorsal nerve-roots. In some forms, such as *Scyllium*, the nerve-roots pass out, not through the plates, but between them; yet the alternation exists the same (see fig. 1, p. 50).

In Hasse's monograph on the vertebræ of Elasmobranchs, to which one naturally turns for information on such a point, the figures (**7**. pl. 34. fig. 14, *Scyllium catulus*, and fig. 22, *Scyllium canicula*) give an incorrect idea of the actual appearance of the vertebræ, for the differences between the calcified and uncalcified parts are exaggerated, while the margins of the cartilage plates, which are of far more morphological importance, are not shown at all. And, further, although Hasse was fully aware of the occurrence of diplospondyly in the tails of these animals (**7**. p. 21), he has indicated in these figures nerve-apertures on consecutive vertebræ. The error cannot be excused on the ground that the part of the vertebral column figured is anterior to that where diplospondyly obtains, for the presence of large hæmal arches proves the contrary. The figures given by Mayer (**13**. pl. 18. fig. 12, and pl. 19. fig. 1, *Scyllium stellare*) are considerably clearer than those of Hasse, but even they leave much to be desired in the delineation of the boundary lines between the neural plates and spines.

The portion of the vertebral column of *Scyllium catulus* (=*stellare*) depicted in fig. 1 is taken immediately below the second dorsal fin, and shows the diplospondylous condition in its most typical form. The hæmal arches (*h*) and the crural plates (*cr*) are fused on the centra (*c*), but the intercrural plates (*ic*), alternating with the crural plates, remain distinct. The hæmal spines (*hs*) are not separate from the hæmal arches, but the neural spines (*ns*) are small cartilages which fit with great regularity over the intervals between the crural and intercrural plates. The dorsal roots of the spinal nerves issue through the foramina (*d*) on the posterior margin of every alternate intercrural plate, while the foramina for the ventral roots (*v*) lie at the lower end of the posterior edge of the crural plates. The dorsal foramina of the right and left sides lie in the same transverse plane; and similarly with the ventral foramina.

This condition of diplospondyly obtains not only in the tail of *Scyllium catulus*, but, as I can testify from personal observation, also occurs in *Mustelus vulgaris*, *Galeus canis*, *Carcharias laticauda*, *Scyllium canicula*, *Cestracion Philippi*, *Acanthias vulgaris*, *Spinax niger*, and *Scymnus lichia*. Considerable confusion has been introduced into the literature of the subject by von Ihering's statement (**9**. p. 229 & p. 233) that *Scymnus* departs from the condition found in *Acanthias* and *Scyllium* by having no double vertebræ in the tail, or only one or two vertebræ with imperforate crural and intercrural plates; for Gadow (**4**. p. 195) has repeated the statement in his memoir on the vertebral column of fishes, without having observed that Mayer (**13**. p. 265) had corrected von Ihering on this point. The figure given by Mayer (**13**. pl. 18. fig. 9) shows that normal diplospondyly commences at the forty-third vertebra in *Scymnus lichia*. In a specimen of this species, which by the kindness of Mr. G. A. Boulenger I was allowed to examine at the Natural History Museum, I found that nine myomeres of the tail were diplospondylous. The first of these segments was situated immediately behind the cloaca, and the hæmal arches commenced at the same place. The relations were thus exactly those which occur in other Selachians.

The passage from the diplospondylous condition in the tail to the monospondylous condition in the trunk is not abrupt, but gradual; and the four or five vertebræ involved in the transition offer an irregularity which deserves more notice than has hitherto been accorded to it. Although three theories at least have been propounded to explain the origin of the caudal diplospondyly, it does not appear to have occurred to anyone to inquire minutely into the detailed structure of these transitional vertebræ; yet they hold, as it were, the key to the situation. The transition is invariably in the proximity of the cloaca, as von Ihering and Mayer (**9**. p. 228, and **13**. p. 261) have already pointed out. It occurs behind the last rib-bearing vertebra, and in front of the vertebra carrying the third or fourth complete hæmal arch (see fig. 2). As a rule it does not extend through more than four or five myomeres, but according to Mayer (**13**. p. 266) six body-segments are involved in *Mustelus*.

The transitional vertebræ do not stand in any constant relation with the dorsal fins, for they are anterior to the first dorsal fin in *Rhina* (**13**. pl. 18. fig. 1), below it in *Scyllium*, between the two dorsals in *Acanthias*, and below the second dorsal in *Scymnus*. Since, however, the dorsal fins are variable in position with respect to the cloaca in different genera, and the transitional vertebræ are definitely related to the position of the cloaca, it is but a logical conclusion that the vertebral transition shall not be related to the position of the dorsal fins. Since caudal diplospondyly occurs in forms like *Acanthias*, *Scymnus*, and *Rhina* which are destitute of the anal fin, the transitional region of the vertebral column cannot bear any relation to this appendage.

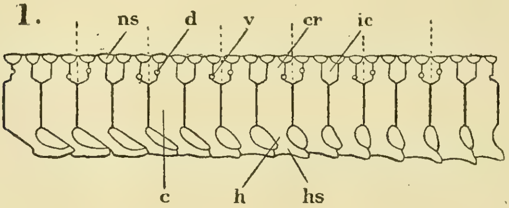
It is evidently to this transition region that Müller is referring, when he writes (**14.** p. 156):—"Bei *Zygæna* fand ich noch das merkwürdige, dass an einigen Wirbeln des mittlern Theils der Wirbelsäule sogar 3 Bogenstücke hinter einander auf einen Wirbel jederseits kommen, während die meisten Wirbel nur 2 Bogenpaare haben." The regularity of the neural plates over the centra in the tail-region was such that the duplicity of vertebræ passed without notice, but the irregularity in the transition region did not fail to catch the eye. Since Müller did not notice the relations of the vertebræ to the neuromeres and myomeres, the differences between the caudal and trunk vertebræ escaped him. According to Mayer (**13.** p. 263), the much misunderstood statement of Kölliker's with regard to *Heptanchus* (*vide postea*, p. 51 footnote) also refers to the few vertebræ in the transition region.

Gegenbaur (**5.** pl. 9. fig. 19) has figured a portion of the vertebral column of *Cestracion*, from the vertebra bearing the last rib to that with the fifth hæmal arch. The figure, however, shows no nerve foramina nor introduction of new intercrural plates, but perfect regularity such as would occur in the trunk region. Although, therefore, this is obviously the region of transition, the irregularities which must have existed are not shown.

The fullest information on the subject is that furnished by Mayer, whose illustrations (**13.** pls. 18 & 19) include the transitional vertebræ of *Scyllium*, *Mustelus*, *Centrophorus*, *Heptanchus*, *Scymnus*, *Acanthias*, and *Rhina*. He roughly describes (**13.** p. 266) the region in question in *Scyllium*, but does not discuss the detailed relations of the neural arches. He merely states that the arches are irregular, and that the bodies may carry three pairs of arches.

In the specimen of *Scyllium catulus* depicted in fig. 2, the irregularities commence immediately behind the last rib-bearing vertebra. The vertebra marked 2 has the crural plate (*cr*) exceptionally broad, and an additional neural spine (*ns*) is superposed upon it. This in itself is an exceptional occurrence, for the neural spines normally lie over the boundary-lines between the neural plates, and not directly over a plate. The third vertebra of the series differs from the second only in that its crural plate is still broader, and that the intercrural plate behind, which should lie over the hinder part of the centrum, has been pushed entirely off, and the third neural spine of this vertebra (*ns'*) has suffered a similar backward displacement. The centra 4 and 5 are the first to show the doubling. They are shorter than the preceding three, but are longer than the half of each of these. The second of the two centra (5) has over it a crural plate and the anterior half of the following intercrural, and

1.



2.

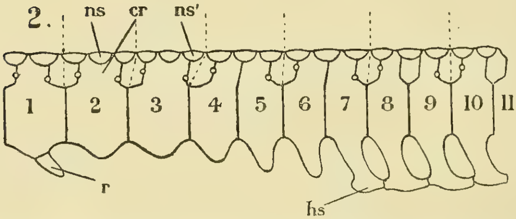


Fig. 1.—*Scyllium catulus*; caudal vertebræ, left side, natural size.

Fig. 2.—*Scyllium catulus*; transitional vertebræ, in the region of the cloaca, immediately below the first dorsal fin; left side, natural size.

c, centrum; *cr*, crural plate; *ic*, intercrural plate; *ns*, *ns'*, neural spines; *h*, hæmal arch; *hs*, hæmal spine; *r*, last rib; *d*, foramen for dorsal root of spinal nerve; *v*, foramen for ventral root.

The dotted lines indicate the hypothetical limits of the perfect vertebræ.

above these are a half and a whole neural spine. The anterior centrum (4) has belonging to it a crural plate and the posterior half of the displaced intercrural in front, and a whole and a half neural spine. That only one half of the intercrural belongs to this vertebra is clear from the fact, that if in figure 2 the line be erased which separates the centra 4 and 5 and their corresponding crural plates, the now single vertebra will be a facsimile of those marked 2 and 3, except for the fact that there are two hæmal processes instead of one.

The next double vertebra (6·7) is a repetition of (4·5) except that the three neural spines occupy the full length of the two centra, and that the hæmal arch on centrum 7 is completed by a hæmal spine (*hs*). The double vertebra (8·9) shows a further departure. Both hæmal arches are complete; and between the two narrow crural plates an intercrural, unnotched on its anterior and posterior borders by nerve foramina, has been introduced. The middle of the three neural spines is thus again exceptionally placed, since it lies immediately over a plate, and not over a boundary line as it did in (4·5) and (6·7). The double vertebra (10·11) is the first of the normal diplospondylous series, and differs from (8·9) only in the greater breadth of the crural plates. A feature of special interest in vertebra (8·9) is that the intercalated intercrural has only appeared on the left side. As seen from the right side, this double vertebra is an exact counterpart of (6·7).

To summarize the above description:—The transition is effected by steps taken in the following order—the broadening of the crural plate and the introduction of an additional neural spine; the division of the centrum and crural plate, and the doubling of the hæmal process; the intercalation of an additional intercrural between the two contiguous crurals. The great advantage attained by this gradual transformation is obviously the avoidance of excessively large or excessively small cartilages, while yet securing a diminution, on the whole, of the antero-posterior length of the elements.

The most recent view on the subject of caudal diplospondyly in Selachians is that expressed by Dr. Gadow, who attributes (4. p. 194) the phenomenon to the "chorda centra" being independent of the "arcualia" and to the difference between the metamerism of the centra and that of the arches. He explains that in the middle of the trunk region of *Heptanchus* the centra are double their normal length, extend through two myomeres, and have four pairs of "dorsalia"*. After stating that it is the

* It is not clear from Dr. Gadow's text whether he is here describing observations of his own, or is merely enlarging upon the unfortunate sentence of Kölliker's (**11.** p. 199) "bei *Heptanchus* im hintern und vordern Theil der Wirbelsäule die Zahl der Wirbel um das doppelte grösser ist als in der Mitte." But in either case, it should not escape notice that Hasse failed to confirm Kölliker's observation, and stated (**7.** p. 46) that this anatomist was probably misled by the deceptive appearance of "ein dunkler, doppelt contourirter

variable length of the chorda centra which causes the discrepancies, he proceeds :—" These apparent irregularities reach their climax in the tail of many Elasmobranchs, where exactly the reverse takes place to what occurs in the trunk, in this way, that the chorda centra are so numerous, or so short, that two of them fall to the share of one true segment. The number of dorsal cartilaginous pieces varies extremely." Now, as a matter of fact, the neural plates are arranged with the greatest regularity, as will be seen by a glance at fig. 1; namely, one plate united with each centrum and one plate intercalated, the median dorsal cartilages being regularly disposed over the intervals. In fact Mayer (whose paper is quoted by Gadow on p. 196) had already written (**13.** p. 266), " Nur die an der Übergangsstelle befindlichen Wirbel zeigen allerlei Unregelmässigkeiten in Lage und Anzahl jener Stücke." The only shark in which I have been able to detect any want of correspondence in the tail region between the neural plates and the centra is *Galeus*. Since, as a rule, the elements of the caudal vertebræ are as regularly disposed as are those of the trunk vertebræ, the " explanation " cannot be considered valid.

Dr. Gadow further observes (**4.** p. 195) that the " intercalation or wedging-in of these various cartilages can be followed from the simplest to the most complicated conditions in the Rajidæ." It is to be regretted that he does not give illustrations of these, for he acknowledges that Hasse's figures do not explain the facts. But it must here be pointed out that the Rays are less primitive than the Sharks; and that the fact of the phenomenon being

---

Streifen, welcher der Mitte der Basen der Neur- und Haemapophysen entspricht und senkrecht verlaufend die überraschendste Aehnlichkeit mit einem Zwischenwirbelgewebe hat." And one year previously to this von Ihering (**9.** p. 222) had suggested that Kölliker's error arose from his counting the neural spines as arches. The figure, moreover, which Mayer has given of *Heptanchus* (**13.** pl. 18. fig. 10) shows the usual Selachian diplospondyly, commencing on the fifty-ninth vertebra. The deceptive bands on the centra mentioned by Hasse are clearly shown, but there is nothing abnormal in the regularity of the neural arches. In the accompanying text (**13.** p. 263) Mayer shows that the statement of Kölliker's is correct if read as referring only to the few transitional vertebræ between the trunk and tail regions. But none of these explanations can apply to Dr. Gadow's assertion (**4.** p. 194) that "each long centrum actually belongs to two true segments"—a statement which cannot refer to the alternation of the intercentral plates with those of the intermuscular septa, for that is normal in Sharks, and would not be worth mentioning.

inexplicable without having recourse to the former is a sign of weakness in the argument. And besides, Dr. Gadow is here disregarding his own word of caution expressed on page 193 of his treatise, "Indeed, mischief enough has been done by the selection of the Rajidæ for the elucidation of fundamental morphological questions."

Much may be said in favour of the contention of Mayer and Gadow (13. p. 266, and 4. p. 195) to restrict the word "vertebra" or "spondylus" to a complete scleromere, equal in value and antero-posterior extent to a neuromere and myomere; although to agree in this is not necessarily to accept the conclusion of the latter writer that "diplospondylous" is a "term without any reasonable meaning." For, after all, these "vertebræ" of the tail of Sharks are so regular and complete that we can scarcely deny them the title. Each consists of a centrum of cartilage, partially calcified, with a conical depression in front and another behind, occupied by persistent notochord. Above each centrum, and united with it, is a pair of cartilaginous plates, and between every two consecutive "vertebræ" a pair of intercalary plates, while located over the intervals between these alternating plates are median dorsal cartilages, twice as numerous as the centra. That is to say, the *structure* of each "vertebra" of the tail is exactly the same (neglecting, of course, the distinctive features such as hæmal arches and absence of ribs) as that of a trunk vertebra, except that every alternate one has no nerve foramina, while all the trunk vertebræ are provided with them.

If, therefore, we deny the caudal "vertebræ" the right to rank as equal to those of the trunk region because of their failure to fall in with the metamerism of the muscular and nervous systems, we must yet admit for them a metamerism of their own, which is almost as perfect as that of the trunk vertebræ. It is certain that there is no such "discrepancy between chorda centra and arches," or "difference between the metamerism of the centra and that of the arches," as Dr. Gadow would have. The only discrepancy occurs in the transition region, where it could hardly be avoided; and even there it only affects four or five segments of the body.

Von Ihering conceived the idea (9. p. 235) that in the primitive Selachians the whole vertebral column was diplospondylous, and that the monospondylous condition is secondary, and has been introduced by a fusion of parts proceeding regularly from before backwards. According to this view, therefore, the fewer double vertebræ in the tail in existing forms of Selachians, the more specialized the fish. But Mayer, in disposing of the case of *Scymnus*, upon which von Ihering placed so much reliance, has shown (13. p. 265) that the idea is altogether untenable. He holds that the diplospondylous condition is secondary, and is due to the halving of the normal vertebræ. Hasse (7. p. 21), although lending active support to von Ihering's theory, at the same time regards every alternate "vertebra" of the tail as intercalated, and therefore not homologous with the others.

Embryology unfortunately throws no light upon the subject. Both Götte and von Ihering (6. p. 418, and 9. pp. 222 & 235) were agreed that the ontogenetic segmentation of the caudal vertebræ was precluded by the disposition of the crural and intercrural plates; and Balfour (1. p. 455) satisfied himself by actual examination of embryos that the duplicity of the caudal vertebræ was not due to secondary segmentation, but was observable so soon as the vertebral column showed any signs of differentiation into vertebræ. The figure given by Klaatsch (10. p. 172, fig. 3) of the longitudinal section of the embryonic vertebral column of *Mustelus* fully confirms the conclusions of this embryologist.

Balfour was inclined to explain the want of correspondence between the metamerism of the caudal vertebræ and that of the nerves and muscles by the fact that the former are differentiated later than the latter. Since, however, he also showed (1. p. 453) that the segmentation of the continuous cartilaginous sheath of the notochord was determined by the muscle segments, and gave good reasons for the fact, the lateness of the differentiation of the vertebral segments cannot be taken as an *explanation* of diplospondyly. It merely leaves open the possibility of other influences coming into play and over-ruling the dominating metamerism of the muscles and nerves.

Caudal diplospondyly being so widely spread among existing Sharks, and the fact that there are no traces of the actual process of doubling during ontogenetic development, point to the conclusion that the condition is a very ancient one. With the object of ascertaining whether palæontology could assist in the solution of the problem, I availed myself of the kind assistance of Mr. A. S. Woodward in examining the specimens of fossil Sharks at the Natural History Museum. The results were disappointing; for, in the absence of the muscles, the only means of deciding the principal metamerism of the tail is by the nerve-foramina, and these could not be made out in any single instance. Yet, judging from the centra of the tail being markedly shorter, in proportion to their height, than those in the trunk region, it is by no means improbable that the diplospondylous condition of the tail is of considerable geological antiquity.

Embryology and palæontology both failing us in our efforts to divine the cause and origin of diplospondyly in Sharks, we are constrained to fall back upon the evidence afforded by the transitional vertebræ, and upon another important fact, that diplospondyly does not extend to the extreme posterior end of the vertebral column. The only reference to this fact that I have been able to discover in the scattered literature of the subject is the remark by Mayer (**13.** p. 267), "Somit entspricht an der Schwanzspitze wenigstens jedem Myotom ein Sclerotom." In the hinder three-fourths of the caudal fin of *Acanthias* the myomeres are as numerous as the centra. The change from the diplospondylous to the monospondylous condition occurs at about the twenty-fourth centrum from the end; but the relations between the vertebræ and the muscle-segments can only be made out for the anterior half of these; for in the hinder part there is scarcely any muscle at all between the skin and the vertebræ. The last ten or twelve vertebræ are imperforate, as already shown to be the case in *Scyllium* by von Ihering and Mayer (**9.** p. 228, and **13.** p. 269), and the little muscular tissue that is attached to these vertebræ is innervated by a backward extension of the nerves supplying the preceding myomeres.

Diplospondyly is thus confined to that part of the body lying between the cloaca and the greater part of the caudal fin; and the questions that most naturally present themselves are these—What advantage does diplospondyly confer on this part of the body, and in what respect would this part suffer if the monospondylous condition prevailed? The answer, it seems to me, can be given in a single word—Flexibility. Those who have watched dogfish swimming in an aquarium will know how important is the "tail," or post-cloacal region of the body, as an organ of locomotion, the paired fins playing but a small part in the actual progression of the body through the water. Yet, when the tail is lashed from side to side, the caudal fin at its extremity is seen not to partake of the general lateral curvature, or only in a minor degree. The caudal fin is chiefly concerned with obtaining a purchase upon the water, so as to constitute a relatively fixed point, about which the rest of the body can be moved by appropriate muscular contraction. Flexibility is thus not required in the caudal fin itself, but is of great advantage in the part of the body immediately preceding. The need for this extreme flexibility ceases in front of the cloaca, for here the body is largely occupied by the alimentary and other viscera, and constitutes, with the head, the most important part of the body, compared with which the post-cloacal part is merely a subservient appendage. And, further, since the body is thicker in the trunk region, the proportion existing between the length and the breadth of a segment is much less than in the tail, and consequently one vertebra to each myomere gives the necessary amount of flexibility.

There are not, in Sharks, synovial articulations between the centra as in Snakes, where the flexibility of the vertebral column is considerable; neither are there zygapophysial articulations between the neural arches as in most Vertebrates. The only movements possible are those due to the slight yielding power of the fibrous tissue around the margins of the centra, and between the various cartilages of the neural arches. To double the yielding power of this separating fibrous tissue would be to weaken the connection between the several vertebræ, and to introduce the possibility of lateral displacement; but by doubling the number of vertebræ in any region, twice the amount of fibrous tissue is introduced, without the above-mentioned disadvantage.

This response by the skeletogenous tissue to the requirements of flexibility of the particular part of the body, is possibly referred to in the following sentence from Gadow (4. p. 192):—"It is obvious that the chondrified chordal sheath is affected by the 'centra of motion,' which establish themselves according to the way in which the fish 'wriggles'."

That the vertebræ must be integral multiples of the segments of the body is evident from the relations which exist between the muscles and the vertebræ. Although a secondary feature (Balfour, 1. p. 453, and Gadow, 4. p. 192), it is a fact, that in the development of Elasmobranch fishes the chondrified sheath of the notochord is uniform and unsegmented at a time when the metamerism of the muscular and nervous system is perfect. As a rule the segmentation of this sheath is determined by the myomeres, in the manner explained by Balfour (**1**. p. 453), so that the vertebræ are as numerous as the myomeres; but there is nothing to prevent the vertebral segments being twice, or even three times, as many as the primary segments. To have fractional parts, however, is obviously impossible. Even allowing that the transition between the trunk and tail regions is beautifully gradual, yet, as will be seen by a glance at figure 2, the last monospondylous skeletal segment (3) is followed immediately by one with two centra and two crural plates (4·5).

The most logical conclusions, therefore, from the facts at command, are, that the condition of diplospondyly in the tail of Sharks is secondary, but of ancient date; and, further, that it is purely adaptive, being calculated to maintain a due proportion between length of centrum and width of body, without diminishing the length of the muscle-segments. In the region of the body from the cloaca to the caudal fin, the demand for increased flexibility is prepotent over the normal tendency of the chondrified chordal sheath to segment in such a way that the centra are as numerous as the myotomes.

This, of course, is not an *explanation* of diplospondyly, it is merely a suggestion for its *raison d'être*. That the diminution in the length of the tail which would be entailed by a shortening of the myomeres, and consequent restoration by this means of the balance between the length of the centra and the width of the body, would be a disadvantage, is also a pure assumption, Indeed, the study of Teleostean fishes shows that a shortening of the tail by the abolition of the terminal vertebræ may, and does occur; and this without any compensating increase in the skeletal parts, for the caudal segments of Teleosteans are monospondylous. But, in this connection, *Amia* comes to our assistance; for here, in spite of a homocercal tail and presumably abbreviated vertebral column, the segments of the caudal axis occur two to each myomere and neuromere (**9**. p. 231). And, as in Selachians, the last segments of the body, namely those in the hinder part of the caudal fin, are monospondylous (Franque, **3**; Kölliker, **12**; Shufeldt, **16**; Hay, **8**; and others).

Whether, therefore, we accept the view of Franque (**3**. p. 10) that in *Amia* those vertebral bodies of the tail which are destitute of neural and hæmal arches have been intercalated between the true vertebræ; that of von Ihering (**9**. p. 235), that the condition is due to the secondary segmentation of vertebræ originally simple; that of Schmidt (**15**. p. 755), that two consegmental vertebræ occurred primitively throughout the body, and now persist only in the caudal region; or that of Baur (**2**. p. 942), and Hay (**8**. p. 5), that the pleurocentrum and hypocentrum together constitute a single vertebra equivalent to those of the trunk region, where the fusion of pleurocentra and hypocentra is assumed to have occurred,—the same general conclusion will apply as that above specified for Selachians, namely, that the universal tendency to develop single vertebral bodies is, in the region between the anus and the caudal fin, over-ruled by the demand for increased flexibility. Indeed, the conclusion might even be further extended to the Stegocephali, in which the embolomerous type of vertebra prevails in the caudal region only.

List of References.

1. Balfour, F. M. — Comparative Embryology. Vol. ii. London, 1881.
2. Baur, G.—"On the Morphology of Ribs." Amer. Nat. vol. xxi., Philadelphia, 1887; pp. 942–945.
3. Franque, H.—Nonnulla ad Amiam calvam accuratius cognoscendam. Berlin, 1847; pp. 14, one plate.
4. Gadow, H., and Abbott, E. C.—"On the Evolution of the Vertebral Column of Fishes." Phil. Trans. Roy. Soc., vol. 186. 1895, B (1896); pp. 163–221, numerous figures in the text.
5. Gegenbaur, C.—"Ueber die Entwickelung der Wirbelsäule des *Lepidosteus*, mit vergl.-anat. Bemerkungen." Jenaische Zeitschrift, vol. iii., Leipzig, 1867; pp. 359–420, three plates.
6. Götte, A.—Die Entwickelungsgeschichte der Unke. Leipzig, 1875.
7. Hasse, C.—Das natürliche System der Elasmobranchier auf Grundlage d. Baues u. d. Entw. ihrer Wirbelsäule. Jena, 1879.
8. Hay, O. P.—"On the Structure and Development of the Vertebral Column of *Amia*." Field Columbian Museum Publications, Zool. Series, vol. i., no. 1. Chicago, 1895; pp. 54, 3 plates.

9. Ihering, H. von.—Das peripherische Nervensystem der Wirbelthiere. Leipzig, 1878.

10. Klaatsch, H.—"Beiträge zur vergl. Anat. der Wirbelsäule. II. Ueber die Bildung knorpeliger Wirbelkörper bei Fischen." Morph. Jahrb., Leipzig, 1893; pp. 143–186, one plate and six figures in the text.

11. Kölliker, A.—"Ueber die Beziehungen der Chorda dorsalis zur Bildung der Wirbel der Selachier und einiger andern Fische." Verhandl. d. phys.-med. Gesell. in Würzburg, vol. x., 1860; pp. 193–242, two plates.

12. Kölliker, A.—Ueber das Ende der Wirbelsäule der Gan oiden und einiger Teleostier. Leipzig, 1860; pp. 28, four plates.

13. Mayer, P.—"Die unpaaren Flossen der Selachier." Mittheil. Zool. Stat. Neapel, vol. vi., Berlin, 1885 (1886); pp. 217–285, five plates.

14. Müller, J.—"Vergl. Anat. der Myxinoiden. I. Osteologie und Myologie." Abhandl. d. könig. Akad. der Wiss. zu Berlin, 1834 (1836); pp. 65–340, nine plates.

15. Schmidt, L.—"Unters. zur Kenntnis des Wirbelbaues von *Amia calva*." Zeitschr. f. wiss. Zoologie, vol. liv. Leipzig, 1892; pp. 748–764, 1 plate and 5 figures in text.

16. Shufeldt, R. W.—"The Osteology of *Amia calva*." U.S. Fisheries Comm. Report for 1883. Washington, 1885; pp. 747–878, 14 plates.